U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Phenomena Identification and Ranking Tables
WHY and HOW

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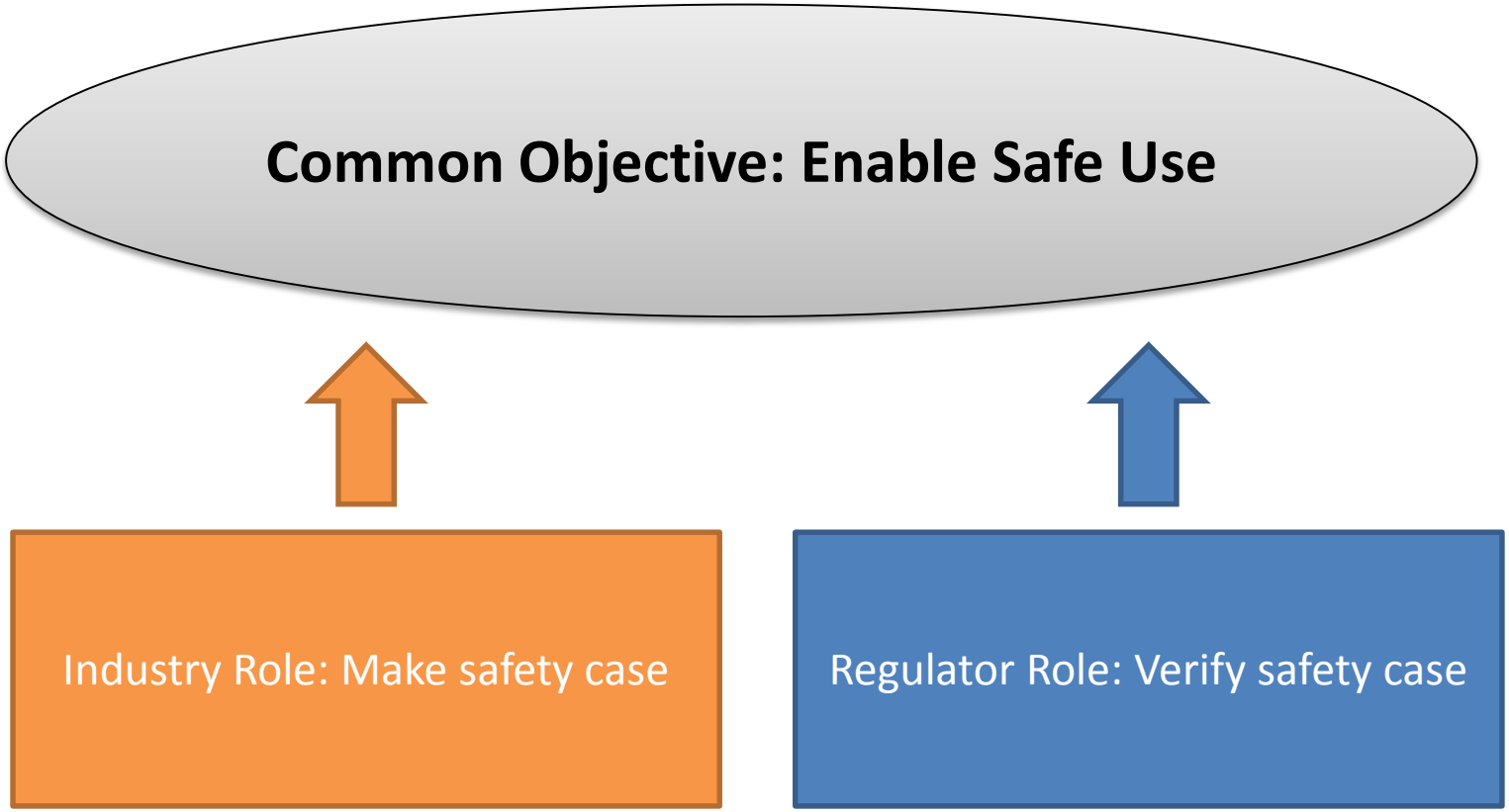
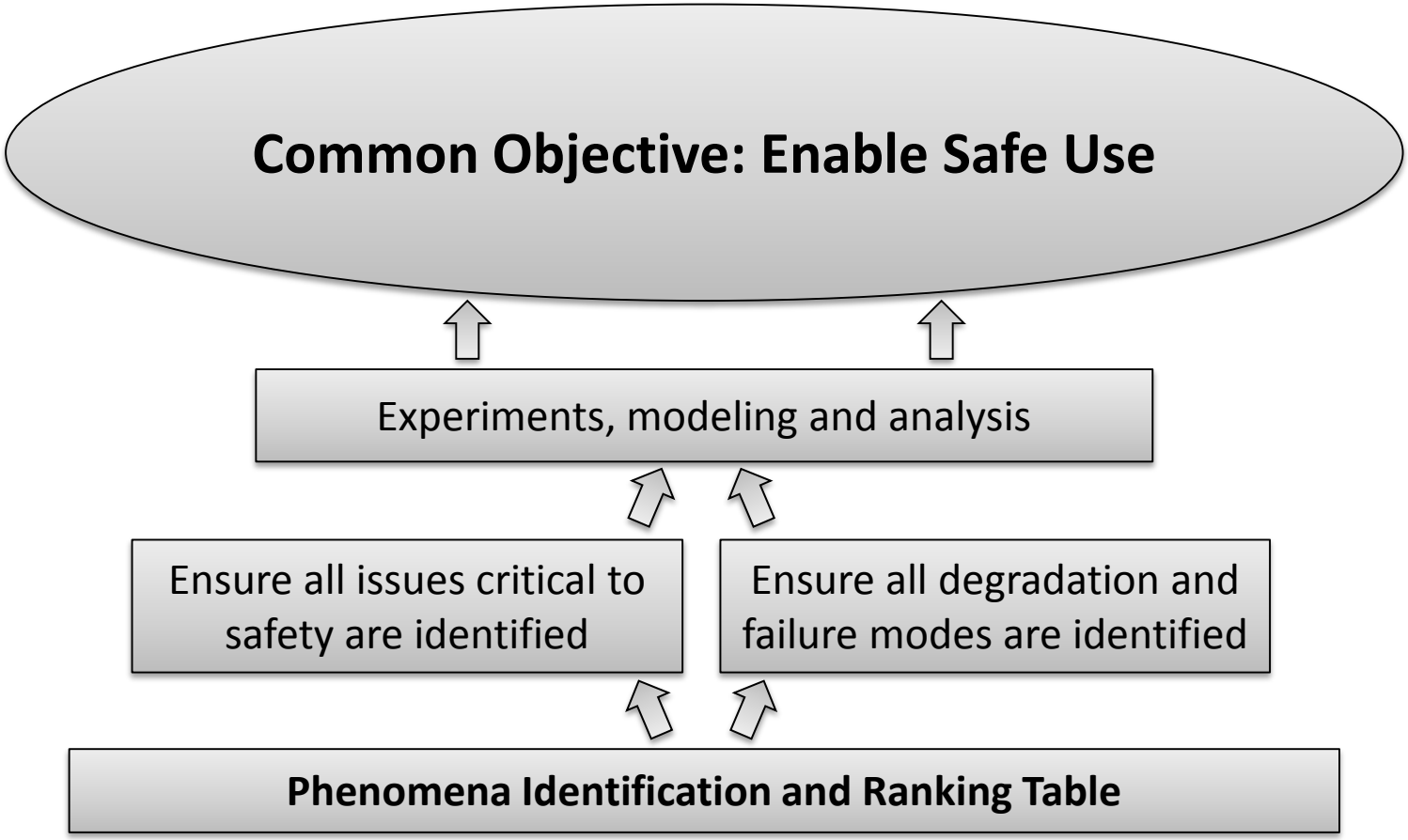
Outline

- Orientation
- The PIRT process
- Recent Examples: *HTGR and High burnup fuel*
- ATF PIRT proposal

One Objective, Separate Roles



PIRT process is part of ensuring safety



The PIRT Process

1. Define the issue that is driving the need for a PIRT
   - Needs associated with batch loading of ATF
   - Needs associated with crediting the benefits of ATF
2. Define the specific objectives for the PIRT
3. Define the hardware and the scenario for the PIRT
4. Define the evaluation criterion
5. Identify, compile, and review the current knowledge base
6. Identify plausible phenomena, that is, PIRT elements
7. Develop importance ranking for phenomena
8. Assess knowledge level (KL) for phenomena
9. Document PIRT results

Recent Example: High Burnup Fuel
Driver

- In mid 1990s, research started to indicate that certain regulatory criteria might not be adequate at high burnups and may not be effective for the new cladding alloys
- New, focused research was needed to ensure that reactor safety was maintained
- A PIRT was conducted to inform research planning

Recent Example: High Burnup Fuel
Approach

- Conducted 3 PIRTS, defined by hardware and scenario (*see step 3*)
  - Rod Ejection Accidents in Pressurized Water Reactors Containing High Burnup Fuel
  - Power Oscillations Without Scram in Boiling Water Reactors Containing High Burnup Fuel
  - Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel
- Considered 4 categories: plant transient analysis, integral testing, transient fuel rod analysis, separate effects testing
- Divided into analytical and experimental working groups
- Determined primary evaluation criterion: cladding failure with significant fuel dispersal for RIAs and cladding fragmentation for LOCA.

Recent Example: High Burnup Fuel
Membership

- PWR Rod Ejection Accidents – 21 members
- BWR Power Oscillations Without Scram – 16 members
- LOCAs in Pressurized and Boiling Water Reactors– 22 members

- Large panels, with overlap where appropriate, between three subjects. Large size meant that votes would be taken to rank items (rather than reach a single, consensus rank).
- Members of the US and international scientific community, many of whom were actively involved in experimental and analytical work related to the behavior of high burnup fuel under accident conditions.
- Panel members voted on only those phenomena for which they had a firm opinion about importance.

Recent Example: High Burnup Fuel
Outcome

- Three reports document the results of this expert elicitation.
  - Phenomenon Identification and Ranking Tables (PIRTs) for Rod Ejection Accidents in Pressurized Water Reactors Containing High Burnup Fuel (NUREG/CR-6742)
  - Phenomenon Identification and Ranking Tables (PIRTs) for Power Oscillations Without Scram in Boiling Water Reactors Containing High Burnup Fuel (NUREG/CR-6743)
  - Phenomenon Identification and Ranking Tables (PIRTs) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel (NUREG/CR-6744)
- PIRT reports did not include conclusions, by design. Implications of the phenomenon rankings are discussed in the staff report, and methods of resolving issues related to fuel damage limits are outlined.
  - Implications from the Phenomenon Identification and Ranking Tables (PIRTs) and Suggested Research Activities for High Burnup Fuel (NUREG-1749)

Recent Example: HTGR
Driver

- The Energy Policy Act of 2005, Public Law 109-58, mandated the NRC and DOE to develop jointly a licensing strategy for the HTGR.
- The licensing strategy required NRC to
  - Develop analytical tools to verify the design and its safety performance
  - Define the research and development activities that the NRC would need to conduct to review the license application.
- A PIRT was conducted to inform research planning

Recent Example: HTGR
Approach

- Conducted 5 PIRTS, defined by major topical areas of the HTGR
  - accident analysis and thermal-fluids including neutronics
  - fission product transport
  - high temperature materials
  - graphite
  - process heat and hydrogen production
- Separate panels of national and international experts were convened to identify safety-relevant phenomena, rank their importance, and assess the knowledge levels in each area

- Note, previously, a separate PIRT was conducted on TRISO-coated particle fuel for VHTR and HTGR technology and documented in a NUREG report

Recent Example: HTGR
Membership

- Accident analysis and thermal-fluids including neutronics - 11 members
  - Covers three subtopics: accident analysis, thermal fluids, and neutronics.
  - Two additional members participated in this panel's evaluations of reactor physics related phenomena.
- Fission product transport – 5 members
- High temperature materials – 4 members
- Graphite – 3 members
- Process heat and hydrogen production– 4 members
- Members in any given panel were selected from a mix of researchers and subject matter experts in academia, national laboratories, and international organizations.

- TRISO-coated particle fuel PIRT had 3 members.
- This panel solicited peer review and comment to enhance their report.

Recent Example: HTGR
Outcome

- Six volume report documents the results:
  - Next Generation Nuclear Plant Phenomena Identification and Ranking Tables (PIRTs) (NUREG/CR-6944)

- TRISO fuel PIRT is documented separately
  - TRISO-Coated Particle Fuel Phenomenon Identification and Ranking Tables (PIRTs) for Fission Product Transport Due to Manufacturing, Operations, and Accidents (NUREG/CR-6844)

Lessons Learned

What makes a PIRT successful?

- **Facilitator is Key –** Responsible for planning and facilitating discussions, documenting the identification and ranking outcomes of the panel
- **Member experience & credentials drive results –** Members should be actively involved in experimental and analytical work on the subject.
- **Documentation creates long-lasting value –** Documenting rationale for rankings allows others to understand & effectively use PIRT results. Allows readers to build on foundation of the PIRT.

ATF PIRTs

- We considered two options for the conduct of ATF PIRT exercises
  - NRC assembles a panel of experts
  - NRC, DOE and industry all provide input on panel experts
- We see the second option as preferable because:
  - it facilitates early alignment on what is important to safety among key stakeholders
  - makes it possible for all stakeholders to rely on the best experts, untainted by a previous expert elicitation on the same subject

Best Practices for Expert Elicitations[1]

- Potential conflict of interest must be carefully considered when selecting experts
  - Panel members must be able to represent their knowledge base, not their organization
- The potential for cognitive bias must be considered and addressed
  - Review common cognitive bias vulnerabilities ahead of elicitation to increase awareness for panel members.
  - Employ a structured process to reduce biases
  - Participatory peer review can be used to monitor the elicitation to avoid significant systematic biases
- Ensure transparency
  - Document input, models considered, process employed, results obtained, caveats and limitations of the inputs, process and results.

1. J. Xing, S. Morrow, "White Paper: Practical Insights and Lessons Learned on Implementing Expert Elicitation," October 13, 2016 (ML16287A734) Response to SRM-COMGEA-11-0001, "Utilization of Expert Judgment in Regulatory Decision Making"

Coordinated PIRT Panels: Industry, DOE and NRC

- The outcome of a PIRT is identification of what phenomenon are important and assessment of the level of knowledge of each phenomenon. This outcome can be used by different entities for distinct purposes without giving rise to organizational conflict of interest
  - NRC would use the PIRTs to inform regulatory requirements
  - DOE would use the PIRTs to prioritize research
  - Industry would use the PIRTs to develop their safety case

Coordinated PIRT Panels: Industry, DOE and NRC

- The PIRT exercises need to be concept specific but not technology specific
- The scope of each exercise needs to be consistent with the concept's degree of departure from the state-of-practice
  - Limited scope elicitation on knowledge gaps may be sufficient for small departures, while comprehensive review of a concept's potential impact on all GDCs may be needed for large departures
  - Initial PIRT steps (to define issue, objectives and hardware/scenario) ensure the scope and depth of the exercise is well define before elicitation begins
- NRC, DOE and industry should prioritize the PIRT exercises according to
  - technology maturity
  - anticipated duration of research programs that support the concepts
- NRC will elaborate on the PIRT process in the final Project Plan to address comments and capture emerging plans